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**The Seasonal Course of Soluble Nitrogen and Phosphate
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Apple and Elberta Peach**

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The Seasonal Course of Soluble Nitrogen and Phosphate Phosphorus in the Shoot Growth of Winesap Apple and Elberta Peach

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Numerous investigators have analyzed woody tissues from various parts of apple and peach trees for different nitrogen compounds. Very little work has been done, however, on the soluble forms of nitrogen, other than nitrate, and on phosphate phosphorus, present in green wood tissue and being used in normal anabolic processes. The various studies clearly indicated that the presence of nitrogen is related to fruitfulness and, in most cases, definite relationships were shown to exist between the insoluble nitrogen content of the parts analyzed and their ability to produce fruit. Recent work by Emmert with some fruit-producing vegetable plants (1, 2, 3) showed a high correlation between growth and fruiting, and the soluble nitrogen and phosphate phosphorus content of the conducting tissues. His findings suggested that similar relationships may exist in fruit trees. Accordingly, it seemed desirable to adapt Emmert's procedure to a study of apple and peach trees, in the investigation reported herein.

The trees studied are in the orchard of the Experiment Station at Lexington. The method of analysis is an adaptation, with some modifications, of Emmert's procedure (2, 3). It is easy and rapid, necessary qualities for this work. The "soluble nitrogen" of Emmert's work and this study is that which is

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extracted from vegetative tissue by treatment with dilute acetic acid; it therefore includes more than that which is in the form of nitrate. Inasmuch as Tiedjens and Robbins (5) and others have shown that plants may use nitrogen in other forms than nitrate, it seems proper, in estimating the active nitrogen in a plant, to include all that is in solution. It is suggested that the use of dilute acetic acid as the extraction reagent approximates fairly closely the makeup of the solution within the cells, tho its concentration of hydrogen ions is greater. Acetic acid also effects the separation of certain colloidal compounds that would be present in a water extract, and thereby prevents the formation of off-color tints which would not be comparable with the colorimetric standards.

PLAN OF WORK

Since determinations of this nature have not been made with apples and peaches, it was deemed advisable to trace the seasonal course of soluble nitrogen and phosphate phosphorus in trees receiving different types of treatment with respect to culture and fertilizer applications. Analysis of the apical part of terminal shoots was made at intervals of one week, on both apples and peaches, over periods of fifty-four and fifty weeks, respectively, so that the growing-season and dormant-season content of these nutrients could be determined. The work was started on March 22, 1935, and the data given for apples include the determinations for April 21, 1936. The data for peaches are for the same dates except that the determinations were concluded on March 24, 1936. No determinations were made from July 3 to August 9, 1935. The trees used were treated as follows:

Apple. Winsap trees were set in March of 1927 and have been grown, since 1929, under four cover-crop treatments, as follows:

Plot 1. Korean lespedeza sod. In order to maintain a good stand, the plot was plowed and reseeded in the spring of 1933, 1935 and 1936.

Plot 2. Non-leguminous cover of millet followed by barley.

Each year, German millet was sown between May 1 and 10, and turned under just before heading, July 20 to August 5, after which the ground was worked frequently until September 1 to 10, when barley was sown. This was turned under April 1 to 10 and the land prepared for sowing millet.

Plot 3. Permanent bluegrass sod. The stand of grass was established in 1930 and has continued good. The grass has been cut occasionally in the summer, and left on the ground.

Plot 4. Sweet clover and soybeans in alternate years. Sweet clover was sown April 15 to 20 and turned under either in the fall of the same year or the next spring. Soybeans were sown about June 1 and turned under in the fall or the next spring.

Peach. The samples for analysis were taken from a block of fifty-four ten-year-old Elberta trees. These trees were treated with different forms of nitrogen fertilizer, as shown by the following statement:

Nitrogen fertilizer treatment of the peach trees:

Row 1. Ammonium sulfate, 4 lbs. per tree, March 20.

Row 2. Buffer.

Row 3. Sodium nitrate, 4 lbs. per tree, applied 2 lbs. March 20, and 2 lbs. June 1.

Row 4. Buffer.

Row 5. No nitrogen.

Row 6. Buffer.

Row 7. Sodium nitrate, 4 lbs. per tree, June 1.

Row 8. Buffer.

Row 9. Cyanamid, 2 lbs. per tree, March 9.

Each row is six trees of fairly uniform size. They carried no crop during the summer, as the fruits were killed by frost on April 16, 1936. The application to Row 7 was made on June 1 for the purpose of increasing vegetative growth without influencing the setting of fruit. The buffer rows received no nitrogen and were not used for sampling. The samples for the no-nitrogen control were taken from trees in Row 5. The entire orchard had a cover of barley which was turned under in early April.

Soil. The peaches and apples are growing on adjacent areas which are separated only by a roadway. The soil is a

fairly heavy clay of the Maury silt loam type and is rich in phosphorus. When the peach trees were three years old, part of them which were set as fillers, were removed so that the root penetration and distribution could be studied. The surface soil is well supplied with humus and is fairly retentive of moisture. At a depth of two and a half to three feet a very impervious hard-pan was found and practically all the peach roots were above this stratum. Only a very few roots had penetrated this hard-pan formation. The soil rests upon limestone at a depth of five to six feet. The apple trees are on an area which is slightly lower in elevation than the peach block and seem less affected by drouthy conditions.

PROCEDURE FOR THE DETERMINATIONS

Sampling. Investigational work with fruit trees has shown that the length of annual shoot growth gives a good indication of the ability of trees to fruit satisfactorily. For this reason, it was decided to analyze the shoot growth for soluble nitrogen and phosphate phosphorus. Numerous tests were made to determine from what position on a tree the shoots for analysis should be taken, and what part of a shoot should be used. These trials resulted in the use of shoot growth arising from the terminal bud of a main branch, rather than from a small lateral branch. During the winter and in the spring before growth started, a section from the terminal portion of the past season's growth just back of the terminal bud, was used. New growth was selected as soon as the shoots were large enough to give an adequate sample for the determinations. Shoots of nearly the same size were chosen and duplicate samples were selected from trees receiving uniform treatment. The leaves were removed immediately and the shoots wrapped in a damp cloth to be brought to the laboratory for weighing.

Shoots chosen at random from a tree would be expected to differ in their percentages of soluble nitrogen and phosphate phosphorus even tho extreme care was taken in their selection. The question arises, whether the variation between the duplicate samples from the same tree was great enough to be significant.

The following tables, covering a period of approximately a year, give the results from duplicate samples of Winesap shoots analyzed at weekly intervals. The analyses were divided into three groups according to season. The t value for testing significant difference between the means of duplicate samples for each group was calculated according to Fisher and the values which t must have to indicate significant difference are placed below the calculated value of t . These values were taken from the probability integral (or t) tables by Fisher. The smaller one indicates a probability of 95 in 100; the larger, 99 in 100. Differences calculated from random samples of these sizes are likely to give values of t less than the smaller number 95 times in 100, and less than the larger number 99 times in 100. The t values for the groups were in no case great enough to indicate a significant difference between the means of duplicate samples. Soluble nitrogen usually varied more between samples taken at the same time than did phosphate phosphorus. This is shown by the somewhat larger t values for soluble nitrogen and by the graphs on the following pages in which the fluctuations are greater in the percentage of nitrogen than in that of phosphorus.

Soluble Nitrogen in duplicate samples from the same winesap apple trees, in parts per million of fresh tissue. 1935-36.

Date	Plot 1		Plot 2		Plot 3		Plot 4	
1935								
March 22	460	536	518	536	485	507	667	667
March 29	417	667	476	556	476	500	625	833
April 5	436	455	490	510	333	355	521	538
April 12	318	362	435	510	139	181	350	362
April 18	249	329	436	481	65	75	311	416
April 26	260	260	347	520	156	174	391	391
May 3	332	347	438	543	159	189	338	391
May 10	318	346	402	422	115	149	305	313
May 18	298	321	332	411	81	129	252	321
May 24	159	208	360	434	45	77	98	100
May 31	186	208	428	462	68	77	112	117
June 7	226	238	260	313	82	106	274	279
June 14	325	357	169	211	103	114	215	241
June 20	340	368	192	240	88	89	333	370
June 26	336	410	169	199	126	136	227	248
July 3	220	260	214	235	80	156	195	249
Average	305.	354.	354.	411.	163.	188.	326.	365.
t value	1.33		1.31		.52		.63	
Significant	2.042, 2.75		2.042, 2.75		2.042, 2.75		2.042, 2.75	
August 9	156	156	313	377	102	128	260	267
August 15	185	192	294	364	177	215	235	345
August 23	156	159	177	233	156	182	291	309
August 29	176	206	180	220	177	200	220	266
September 5	123	155	211	288	162	197	297	326
September 12	198	211	211	239	83	156	231	273
September 18	136	143	192	235	96	122	216	246
September 25	200	267	105	157	136	140	227	230
October 2	113	137	117	220	154	157	214	214
October 9	154	177	143	175	100	118	155	167
October 16	132	140	180	200	96	106	190	260
October 23	159	169	122	182	143	148	187	198
October 29	138	140	200	206	104	121	175	187
November 6	72	111	114	136	111	122	206	242
November 13	225	289	165	190	146	153	303	303
November 20	165	215	132	179	145	146	167	220
November 27	132	136	106	125	153	163	153	159
December 4	97	108	108	113	78	91	79	82
Average	151.	173.	171.	213.	129.	148.	211.	239.
t value	1.47		1.92		1.74		1.33	
Significant	2.032, 2.729		2.032, 2.729		2.032, 2.729		2.032, 2.729	
December 11	83	84	142	157	57	106	74	134
December 18	62	64	81	89	72	76	74	81
December 26	51	52	50	52	56	57	68	68
1936								
January 2	49	51	49	56	37	38	69	79
January 8	77	103	115	136	104	130	89	168
January 15	88	132	83	115	82	90	82	86
January 22	98	120	104	114	81	86	99	119
January 29	79	79	93	120	85	88	74	93
February 5	81	91	81	93	87	97	118	123
February 12	78	99	89	112	81	87	101	104
February 19	79	84	85	90	77	81	102	106
February 25	75	87	86	109	70	83	82	95
March 3	74	76	100	120	74	75	77	83
March 10	89	105	95	118	107	109	110	124
March 17	126	146	226	246	137	197	163	185
March 24	129	139	216	244	142	143	201	244
March 31	231	238	242	297	159	207	248	280
Average	91.	103.	114.	133.	89.	103.	108.	128.
t value	.80		.90		1.07		1.06	
Significant	2.037, 2.740		2.037, 2.740		2.037, 2.740		2.037, 2.740	

Seasonal Course of N and P in Fruit-tree Shoots 165

Phosphate Phosphorus in duplicate samples from the same winesap apple trees, in parts per million of fresh tissue. 1935-36.

Date	Plot 1		Plot 2		Plot 3		Plot 4	
1935								
March 22	178	229	287	309	300	322	188	213
March 29	320	320	267	320	291	320	291	320
April 5	246	328	278	282	244	278	200	241
April 12	130	147	167	227	101	131	108	131
April 18	99	103	103	114	34	34	90	110
April 26	61	95	78	95	51	67	51	67
May 3	109	122	102	122	68	63	62	70
May 10	122	132	111	147	60	64	49	59
May 18	138	148	80	84	55	62	73	80
May 24	89	189	69	111	61	77	56	106
May 31	84	120	65	88	81	83	75	75
June 7	100	103	95	97	113	121	89	103
June 14	69	99	74	76	95	95	86	101
June 20	139	143	93	109	104	111	127	133
June 26	116	143	97	137	98	111	139	172
July 3	122	132	118	136	84	108	143	143
Average	133.	160.	130.	153.	115.	128.	114.	133.
t value	1.09		.82		.42		.76	
Significant	2.042, 2.750		2.042, 2.750		2.042, 2.750		2.042, 2.750	
August 9	120	169	196	208	182	222	159	167
August 15	161	167	204	213	200	208	164	169
August 23	149	160	156	161	222	233	167	179
August 29	103	133	147	161	222	250	167	200
September 5	130	130	111	154	182	200	147	182
September 12	101	103	98	119	167	167	145	167
September 18	70	119	139	143	200	213	145	159
September 25	92	116	110	112	167	238	133	156
October 2	103	112	99	125	143	175	83	135
October 9	88	93	96	96	133	161	109	112
October 16	141	154	95	123	105	115	147	154
October 23	121	179	125	137	154	200	102	143
October 29	80	89	81	85	154	175	76	96
November 6	115	115	93	115	156	164	96	110
November 13	75	79	79	105	135	147	89	94
November 20	110	116	83	99	145	167	80	95
November 27	90	91	68	85	167	182	111	139
December 4	97	98	103	104	164	179	100	104
Average	108.	123.	116.	130.	167.	189.	123.	142.
t value	1.64		1.15		.86		1.73	
Significant	2.032, 2.729		2.032, 2.729		2.032, 2.729		2.032, 2.729	
December 11	90	100	92	103	149	161	70	71
December 18	95	104	74	75	152	164	79	80
December 26	62	63	88	91	133	161	68	93
1936								
January 2	68	78	74	75	122	133	71	75
January 8	76	81	67	74	105	116	63	81
January 15	65	70	61	65	100	108	65	77
January 22	65	67	63	67	104	115	68	75
January 29	52	56	83	83	75	81	52	53
February 5	52	53	50	55	56	64	56	65
February 12	106	109	51	59	76	102	57	61
February 19	72	93	51	60	83	95	83	83
February 25	69	71	60	71	65	76	84	91
March 3	62	63	66	68	87	118	68	72
March 10	91	99	108	115	114	127	100	115
March 17	92	102	99	101	147	154	95	99
March 24	111	128	128	141	143	154	123	125
March 31	110	122	128	135	169	185	112	143
Average	79.	86.	79.	85.	111.	124.	77.	86.
t value	.97		.64		.80		1.14	
Significant	2.037, 2.740		2.037, 2.740		2.037, 2.740		2.037, 2.740	

The question of whether trees within a plot, all of which had received the same treatment, would differ considerably in soluble nitrogen and phosphate phosphorus was considered. Two sets of determinations were made within a short time of each other so that the data could be averaged. Duplicate samples were taken from each tree in each plot. The results are recorded in the following table:

Soluble nitrogen and phosphate phosphorus in individual apple trees, as parts per million of fresh tissue. Each number is the average of 4 determinations.

	Tree 1	Tree 2	Tree 3	Tree 4	Range, as percent of the average
Soluble nitrogen					
Plot 1	320	348	343	304	13.4
Plot 2	438	433	416	375	15.2
Plot 3	168	158	150	128	26.5
Plot 4	315	307	328	347	12.3
Phosphate phosphorus					
Plot 1	218	249	175	165	41.6
Plot 2	198	215	202	202	8.3
Plot 3	259	246	240	261	8.3
Plot 4	173	200	214	199	20.9

Distribution of Nitrogen and Phosphate. Shoot growth arising from lateral buds of peaches showed a smaller percentage of soluble nitrogen and phosphate phosphorus than was found in shoots from terminal buds. As shoot growth in the season continued to elongate and enlarge, the apical part, excluding the terminal bud, was used. In older wood and with the larger portions of the basal part of shoots, the greater quantity of more mature tissue resulted in a smaller percentage of soluble nitrogen and phosphate phosphorus being found. The portion which gives the higher analysis was considered to be more accurate for determining the quantities of these materials that were available for anabolic processes. The percentage of nitrogen was more variable than that of phosphorus, in wood of any age, and the phosphorus content of the wood varied less than the nitrogen content, from the tip to the basal portion of the current season's

shoots. The following table gives the average of five sets of determinations made on different sections of Winesap apple and Elberta peach shoots in May, 1935. The results are given in parts per million of the green tissue. Each figure is the average of duplicate samples.

Soluble nitrogen and phosphate phosphorus in different parts of apple and peach shoots.

Part Used	WINESAP		ELBERTA	
	N	P	N	P
Apical third	116	73	136	106
Median third	92	74	106	103
Basal third	54	74	89	98

Tests of leaves showed no correlation between the soluble nitrogen content and the conditions under which the trees were growing. It appears that the rapid growth and utilization of the nutrients makes it inadvisable to use leaves for analysis.

Extraction. A one or two gram sample from the apical third of the terminal shoot was used. The weighed sample was cut into thin disks with sharp pruning shears and placed in a mortar. Approximately $\frac{1}{2}$ gram of phosphorus-free charcoal (4) was added and 3 or 4 grams of sharp sand that had been washed and ignited. An accurately measured quantity, 10cc. or 20cc.* of 2 percent acetic acid was added and the sample was finely ground. The extract was filtered into a 25cc. test tube. It was tested for both soluble nitrogen and phosphate phosphorus as described below.

Soluble Nitrogen. To .5cc. of the extract in a 25cc. test tube a little sodium chlorate about the size of a grain of wheat was added and 1cc. of fuming sulfuric acid (15% SO_3) was run in rapidly so that the solution boiled vigorously and complete oxidation of organic material was accomplished. The chlorine evolved by the reaction must be cleared from the tube by shaking and blowing across the top. As soon as the solution was perfectly clear .5cc. of phenoldisulfonic acid was added and

* Mature wood tissue absorbs and holds the extraction liquid so that 10 cc. of acetic acid on a two-gram sample gives hardly enough extract for the determination of both nitrogen and phosphorus.

mixed well. This was allowed to stand for about a minute and approximately 5cc. of water was added and the solution again mixed well. Neutralization of the acid solution and the development of the yellow nitrogen color was accomplished by adding 40% sodium hydroxide solution from a pipette, until the maximum yellow color developed. The solution was made to 20cc. with water and compared with a standard in a colorimeter. The standard used contained .0025mg. of nitrogen as NO_3 in 1cc.

Phosphate Phosphorus. To 3, 4 or 5cc. of the extract, depending on the amount available, a few cc.'s of water, 2cc. of 2.5% solution of ammonium molybdate in 5 normal sulfuric acid and one cc. of 1-2-4 aminonaphthol sulfonic acid reagent were added. The volume was made to 20cc. with water and after standing a short time to allow the full blue color to develop, the amount of phosphorus was determined colorimetrically with a standard containing .002mg. of phosphorus as PO_4 in each cc. of the solution.

RESULTS

Graphs 1, 2, 3 and 4 show the course of soluble nitrogen and phosphate phosphorus in Winesap trees growing in the plots which received different cover-crop treatments. Determinations were made from March 22, 1935, to November 6, inclusive. Graphs 5, 6, 7 and 8 are for the same trees and cultural treatments but cover the period from November 6, 1935, to April 21, 1936. The determinations made on peach trees during the growing season are shown on graphs 9, 10, 11, 12 and 13, and determinations made on the same trees during the dormant period of 1935-36 are given in graphs 14, 15, 16, 17 and 18. The findings for all graphs are the average of two independent determinations which were made at one time. The samples, for the most part, were taken from the same trees each time. The graphs showing the growing season determinations for soluble nitrogen and phosphate phosphorus, on both apples and peaches, also show the rainfall in inches of precipitation per week. Any one column of rainfall represents the amount that fell during the week preceding the date on which nitrogen and phosphorus determinations were made.

DISCUSSION

Apple—Growing Season. In all trees, regardless of the kind of cover crop, the soluble nitrogen in the tissues was at a comparatively high level in the spring before growth started. Soon after the buds opened and growth began, the soluble nitrogen and, likewise, the phosphate phosphorus, were rapidly lowered, presumably thru their utilization in growth processes. The comparatively high percentage of soluble nitrogen in early spring could have come from either of two sources; from a change of insoluble nitrogen that had been held as a storage form within the dormant tissues of the tree, or brought from the soil to the growing tips just before growth started. The latter suggestion seems questionable because the soil was still frozen during part of the time the largest amount of soluble nitrogen was found in the twigs. Nitrogen in the nitrate form is not present in the surface soil in any appreciable amount during the winter, and its accumulation does not begin before the soil has been warmed to the extent that microorganisms are able to work.

The soluble nitrogen continued at a moderately high level thru the period of vegetative activity and dropped to a lower point as the season progressed. This was true of practically all the trees except those growing in bluegrass sod. The nitrogen level in these remained low during most of the season. Throughout the year, the percentage of soluble nitrogen in the tissues was considerably higher than that of phosphate phosphorus, except in the trees growing in the bluegrass sod. In these the soluble nitrogen was always lower than in those on the other plots and, in many instances, the phosphorus content was greater than that of soluble nitrogen. The largest percentages of soluble nitrogen were found in trees in the barley and millet plot and also in the sweet clover-soybean plot. The trees which contained the larger percentages of soluble nitrogen made the greatest increases in circumference growth and the foliage on them was of a darker green color.

The average percentage of soluble nitrogen in the trees where millet and barley were used as a cover crop, was just as

high as in those where the legume crops, sweet clover and soybeans, were grown. In both cases the cover crops were turned under while they were still in a succulent condition. Whether the total nitrogen in the soil where the barley and millet were used remained at as high a level as in the plot where the legumes were grown was not determined. It appears that the large amount of green material that was incorporated with the soil when the millet and barley were turned under may have stimulated the activity of nonsymbiotic nitrogen-fixing organisms to the extent that the available nitrogen in this plot remained at a high level.

The trees in the lespedeza plot were not so high in soluble nitrogen as were those in either the millet or sweet-clover plots, yet they grew satisfactorily and the foliage was fairly dark in color. The trees in bluegrass grew slowly and the leaves lacked the dark green that was characteristic of the others. During the past four seasons, the trees in bluegrass sod yielded somewhat more than those in the other plots. From a comparison of the growth made by trees in the different plots, it appears that all others will soon surpass those in bluegrass sod, in yielding ability, because of the greater amount of potential bearing surface which they possess.

Because of the differences found in the percentages of soluble nitrogen during active vegetative growth and later on in the season, after growth had been completed, it appears that the uptake and transfer of nitrogen by these trees were regulated pretty largely by their need for nitrogen. After length growth for the season had ceased and terminal buds had been formed, the amount of soluble nitrogen translocated to the twigs became increasingly smaller.

The soil from the plots was analyzed for nitrate nitrogen at intervals thruout the summer. The largest amount was found during the period when tree growth was most active. The shoots at this time contained more soluble nitrogen than at any other time during the growing season. In general, as the soluble nitrogen in shoots increased, the phosphate phosphorus decreased, presumably because of its utilization in growth.

With the apple trees, the rainfall in any particular week preceding the chemical determinations seems to have had little effect on the content of soluble nitrogen and phosphate phosphorus. This was not true of the peach trees, as will be shown later, possibly because the greater distribution and penetration by the apple roots made these trees less subject to injury during dry weather.

The following tables give the averages of soluble nitrogen and phosphate phosphorus of Winesap shoots from March 22, 1935, thru December 26, 1935, for each of the cover-crop treatments, and the *t* values for testing significant differences in soluble nitrogen and in phosphate phosphorus for the possible pairs of plots.

Soluble nitrogen and phosphate phosphorus in apple shoots.

Average, March to December, 1935.

Cover crop	Nitrogen	Phosphorus
	ppm	ppm
Lespedeza	227	127
Millet and barley	267	128
Kentucky bluegrass sod	149	152
Sweet clover and soybeans.....	264	125

Values of *t* for testing significant differences.

Cover crops compared	Soluble nitrogen	Phosphate phosphorus
	<i>t</i>	<i>t</i>
Bluegrass vs. lespedeza	<u>3.09</u>	1.79
Bluegrass vs. millet and barley	<u>4.20</u>	1.62
Bluegrass vs. sweet clover and soybeans.....	<u>4.01</u>	1.95*
Lespedeza vs. millet and barley	1.33	.08
Lespedeza vs. sweet clover and soybeans.....	1.20	.17
Millet and barley vs. sweet clover and soybeans	.09	.23

The *t* values thruout this paper were calculated by using the

* Fairly significant: The probability that the difference is due to causes other than random sampling and therefore is a true difference, is 90 or more in 100. The figures underscored are highly significant; that is the probability that the difference is a true one, is 99 or more in 100.

following formula which corresponds to R. A. Fisher's formula for small samples.

$$t = \frac{M_1 - M_2}{\sqrt{\frac{(\sum X_1^2 - M_1 \sum X_1) + (\sum X_2^2 - M_2 \sum X_2)}{N_1 + N_2 - 2}} \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

The differences in soluble nitrogen between the trees growing in bluegrass sod and those of the other cover-crop plots are in keeping with the findings of other investigators who have shown that one of the most harmful effects that sod has upon trees is that of reducing the available nitrogen supply. Altho only one of the comparisons for phosphorus indicates a significant difference, the trees in bluegrass were practically always higher in this element than were the trees in the other plots. Deficiency of soluble nitrogen and the smaller amount of growth made by the trees in bluegrass sod may account for the accumulation of phosphorus in the shoots.

Apple—Dormant Season. Comparatively small differences are shown in the percentages of soluble nitrogen and phosphate phosphorus in apple twigs during the dormant season, regardless of their condition during the preceding growing period. Trees under conditions that were apparently most favorable for growth contained approximately the same amount of soluble nitrogen during the dormant season as trees which had grown poorly because they were insufficiently supplied with available nitrogen. There were no significant differences in either nitrogen or phosphorus between trees which received different treatments. The level of soluble nitrogen in twigs was very low from December 1, 1935, to March 24, 1936, on all plots, and the fluctuations from week to week were comparatively small. The phosphate phosphorus content of apple shoots or twigs varied less than the nitrogen content during either the growing or dormant season. During early spring the percentages of soluble nitrogen and phosphate phosphorus gradually increased until a relatively high point of about 500 p.p.m. of nitrogen and 300 p.p.m. of phosphorus was reached at about the time spring growth began.

Peach—Growing Season. There were striking differences between the percentages of soluble nitrogen in apple and peach shoots in late summer. In early spring, just before growth started, the two were about equal and for a period of two or three weeks during which early rapid vegetative growth was taking place, the soluble nitrogen in peach shoots was rapidly reduced. From the first of June until the end of the growing season the percentage of soluble nitrogen in peach shoots was several times greater than that found in apple shoots. The high point of soluble nitrogen in peach shoots was reached comparatively late in the season, while in apple shoots at this same time it was at a rather low level. Peach trees continue to grow much later in the summer than apple trees and soluble nitrogen is present in the shoots during this whole period of vegetative activity. The fact that comparatively more shoot growth is made by peach than by apple trees may give added proof of the need for a greater quantity of available nitrogen. In further contrast with apple, the low period for soluble nitrogen in peach occurred thru April and May. In apple during this same period the percentage of nitrogen continued at about its highest level for the growing period.

The use of either sodium nitrate or ammonium sulfate, as the source of nitrogen, resulted in a large percentage of soluble nitrogen being found in the shoots in late summer. Sodium nitrate applied at the rate of four pounds per tree, June 1, gave a high point in soluble nitrogen in shoots at an earlier date than ammonium sulfate applied at the same rate per tree on March 25. Calcium cyanamid becomes slowly available to the trees and this is shown by the high point of soluble nitrogen in shoots that was reached late in the season.

As with apple, but to a greater extent, nitrogen in peach shoots was more variable than phosphorus. In contrast with apple, the rainfall had a very noticeable effect on the percentage of soluble nitrogen in peach shoots. Periods of low precipitation resulted in nitrogen accumulation, probably because growth was retarded and nitrogen not used. The exception to this point was noted from June 20 to 26, during which time soluble nitro-

gen in shoots continued to increase even tho rainfall for that period was large. The explanation for this exception may be that rainfall for the four weeks preceding June 20 was only moderate and that the precipitation for the week in question came almost wholly at one time, which resulted in a large amount of run-off. Check trees which received no nitrogen fertilizer averaged lower in soluble nitrogen and higher in phosphate phosphorus than trees which were fertilized. Also, the fluctuations in nitrogen in these trees were much more apparent than in the others.

Phosphate phosphorus averaged considerably lower than soluble nitrogen in peach shoots but about the same as in apple. It varied but little from week to week in normal trees and there appeared to be no period during the growing season when any definite high point was reached. The fluctuations which occurred apparently were due to variations in soluble nitrogen and resulting growth processes which, in turn, were noticeably affected by rainfall.

Peach—Dormant Season. The average percentage of soluble nitrogen in peach shoots during the dormant season was considerably greater than that in apple shoots. The fluctuations during the winter months were not so great, however, as during the summer. The phosphate phosphorus was maintained at nearly the same level in winter as in summer and varied but little from week to week.

The highly significant differences between the percentages of soluble nitrogen in peach and apple twigs during the dormant period give an indication that winter hardiness may be definitely associated with the content of soluble nitrogen in twigs at the time the cold occurs. In comparing the peach and apple as to their ability to withstand severe cold, it is, of course, well known that the apple possesses greater hardiness. The suggestion is offered that analysis of twigs for soluble nitrogen, made during the dormant season, may serve as a valuable index of the comparative hardiness of different fruits or even of different varieties.

The outstanding differences between the percentages of

soluble nitrogen in apple and peach twigs during the winter months prompted the testing of these data for significant difference between soluble nitrogen in apple shoots during the summer and winter and soluble nitrogen in peach shoots during these same periods. The differences for phosphorus during these periods for both apple and peach also were tested for their significance.

Values of *t* for testing significant differences in soluble nitrogen and phosphate phosphorus determinations between summer and winter, in Winesap apple and Elberta peach trees.

Treatment	Values	
	Nitrogen <i>t</i>	Phosphorus <i>t</i>
Winesap Apple		
Korean lespedeza	5.24	4.19
Millet and barley	5.93	3.99
Bluegrass sod	2.48*	1.48
Sweet clover and soybeans	5.09	3.94
Elberta peach		
Ammonium sulfate	.67	5.24
Nitrate, divided	.73	2.51*
Check, no nitrogen	.81	2.05*
Nitrate, June 1	1.40	2.46*
Cyanamid, March 9	.44	2.78

With Winesap apple trees the difference in percentage of soluble nitrogen in shoots during summer and winter was highly significant. The lower *t* value for the trees in sod was not due to a lower percentage of nitrogen in twigs during the dormant season but to a low content during the summer months. The same holds true for phosphorus except that the trees in sod had even a larger percentage of phosphorus in dormant twigs than did trees in other plots.

With Elberta peach the mean of soluble nitrogen for the

* Significant: The probability that the difference is due to causes other than random sampling and therefore is a true difference, is 95 or more in 100. Values of *t* below 2.609, for the number of items used in these computations, are not considered significant. The figures underscored are highly significant; that is the probability that the difference is a true one, is 99 or more in 100.

dormant period was somewhat greater in three out of the five treatments than during the growing season. These results are particularly striking in comparison with apple where the percentage of soluble nitrogen in winter was much lower than in summer.

SUMMARY

Soluble nitrogen and phosphate phosphorus determinations of apple and peach shoots and twigs were made at weekly intervals over a period of fifty-four weeks for apple and fifty weeks for peach.

The percentages of soluble nitrogen and phosphate phosphorus in apple shoots were significantly different between summer and winter even where trees were growing in bluegrass sod.

Soluble nitrogen in apple shoots averaged considerably more thruout the growing season than phosphate phosphorus in the same samples, except with trees growing in bluegrass sod, and the nitrogen was more variable than the phosphorus at any time.

Soluble nitrogen in apple twigs was maintained at a very low level during the dormant period. The soluble nitrogen in peach shoots averaged less than that of apple shoots thru the early part of the growing period but was many times greater during late summer and fall.

The percentages of phosphate phosphorus in the shoot growth of apple was maintained at nearly the same level thruout the year and a similar relationship occurred in peach.

The percentage of soluble nitrogen in dormant peach twigs was much greater than in dormant apple twigs.

In general, as soluble nitrogen in shoot growth increased, phosphate phosphorus decreased and the reverse of this statement was true also under average conditions.

Periods of low precipitation resulted in accumulation of soluble nitrogen in peach shoots while ample rainfall reduced the percentage of this nutrient, presumably by its utilization in growth.

The percentage of soluble nitrogen in apple shoots was not

influenced so much by the distribution of rainfall as was the percentage in peach shoots.

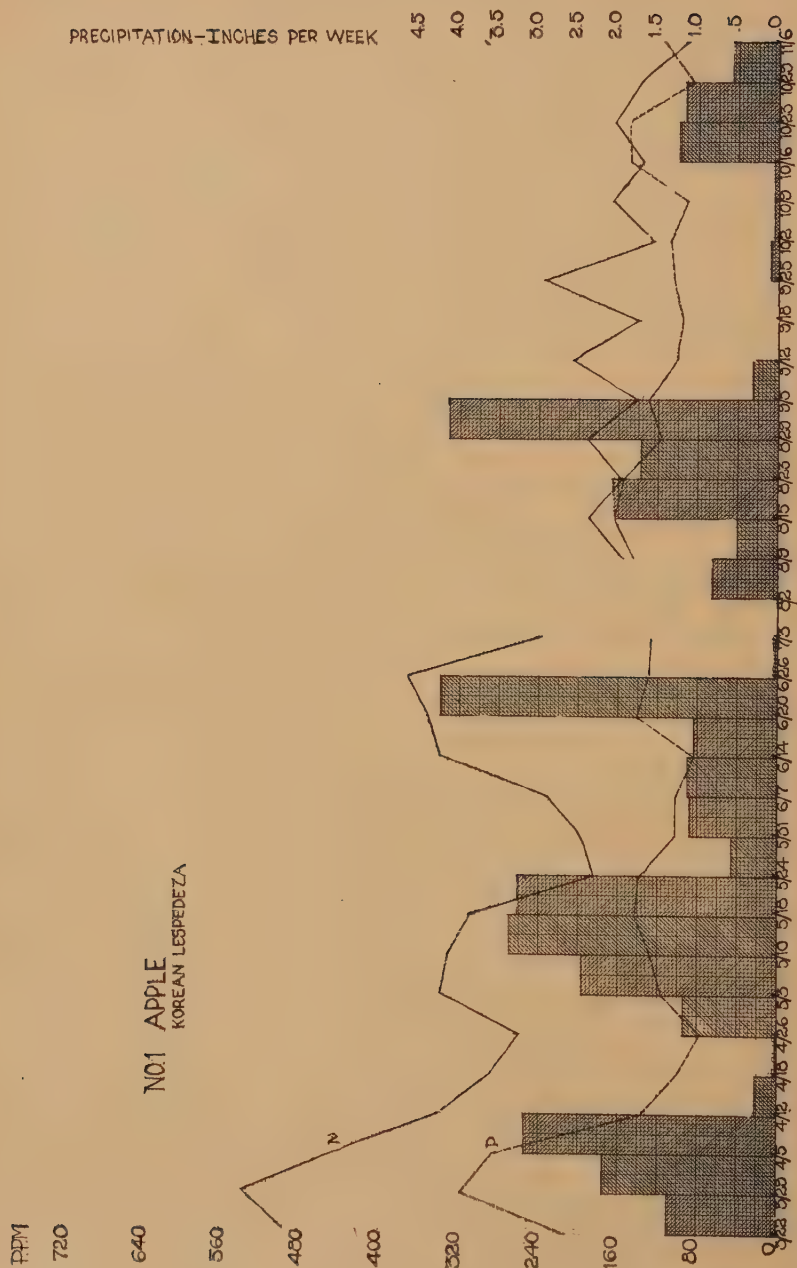
With Elberta peach, the trees which received ammonium sulfate and sodium nitrate in early spring and also those which received no nitrogen fertilizer averaged somewhat higher in soluble nitrogen during the winter months than during the complete growing period.

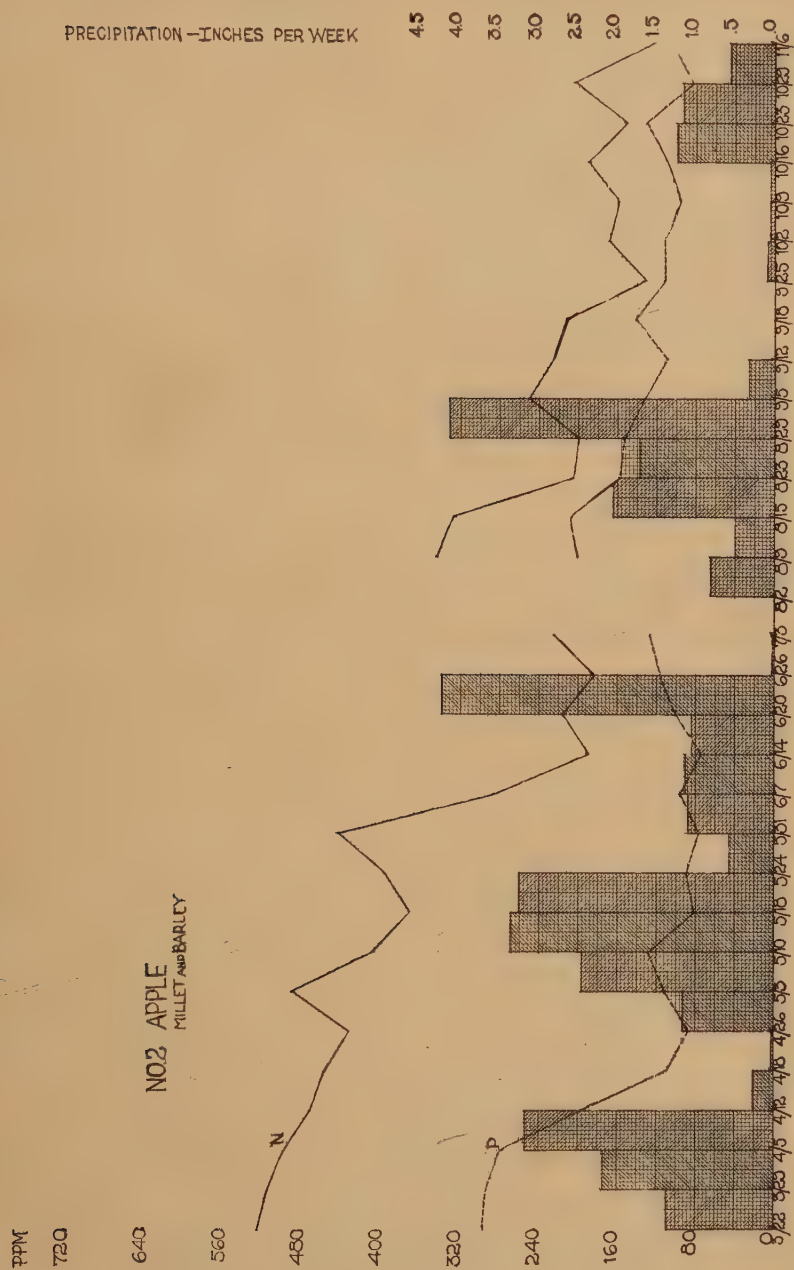
There was no significant difference in soluble nitrogen in peach trees during summer and winter, regardless of fertilizer treatment.

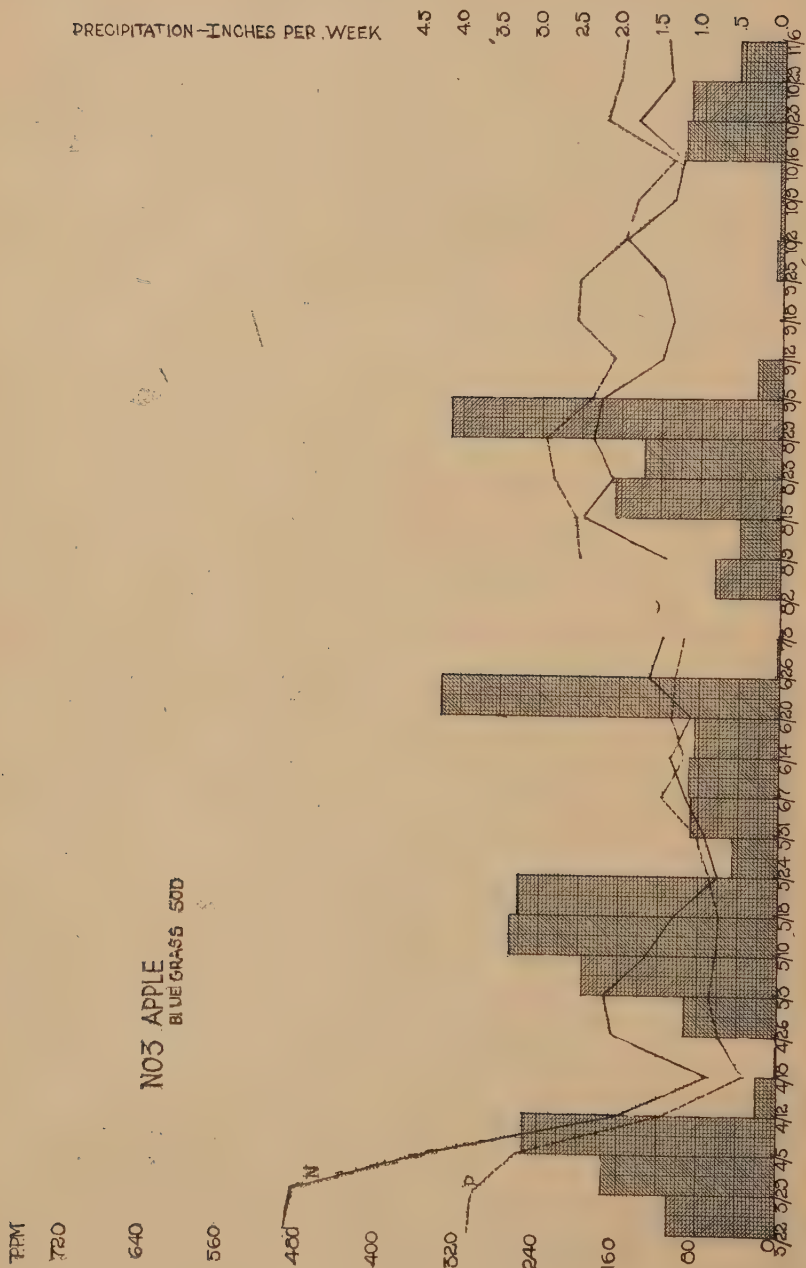
Apple trees growing in bluegrass sod are limited in growth by a lack of available nitrogen and this was shown definitely by the low percentage of soluble nitrogen in the shoots.

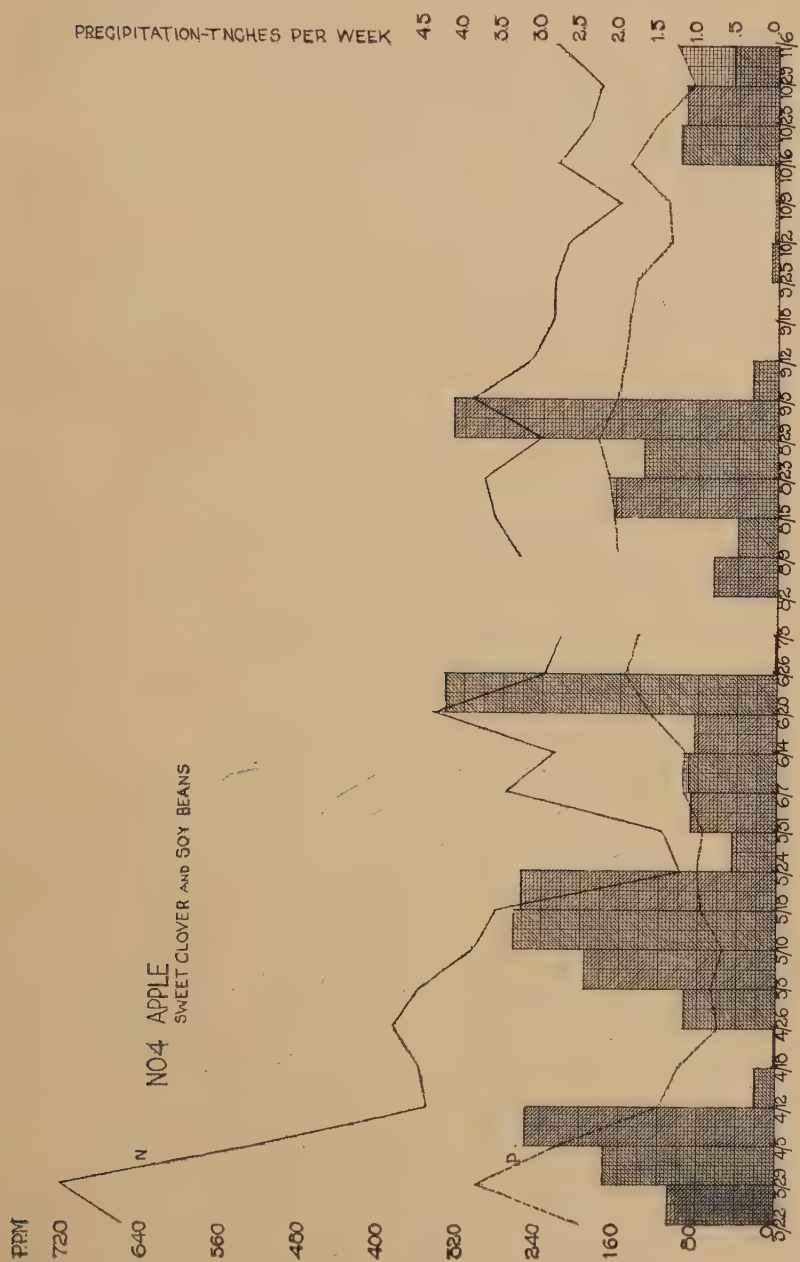
The shoots of Winesap apple trees on a plot where the non-leguminous crops, millet and barley, were used as a cover, averaged fully as high in the percentage of soluble nitrogen as shoots of trees where sweet clover and soybeans were grown.

Increase of the tree trunks, in circumference, general vegetative vigor, and leaf color of apple trees were as good where millet and barley were grown as where sweet clover and soybeans were used.









PPM

720

640

NO.5 APPLE
KOREAN LESPEDEZA

560

480

400

320

240

160

80

1/13 1/20 1/27 12/4 12/11 12/18 12/26 1/2/30 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24 3/31 4/7 4/14 4/21

PPM

720

640

NO.6 APPLE
MILLET AND BARLEY

560

480

400

320

240

160

80

1/13 1/20 1/27 12/4 12/11 12/18 12/26 1/2/30 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24 3/31 4/7 4/14 4/21

PPM

720

640

NO.6 APPLE
MILLET AND BARLEY

560

480

400

320

240

160

80

Seasonal Course of N and P in Fruit-tree Shoots 183

P. P. M.

640

NO.7 APPLE
BLUE GRASS 500

560

480

400

320

240

160

80

0

1/1/13 1/1/20 1/1/27 1/2/4 1/2/11 1/2/18 1/2/26 1/2/36 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24 3/31 4/7 4/14 4/21

PPM

720

620

NO.8 APPLE
SWEET CLOVER AND SOY BEANS

560

480

400

320

240

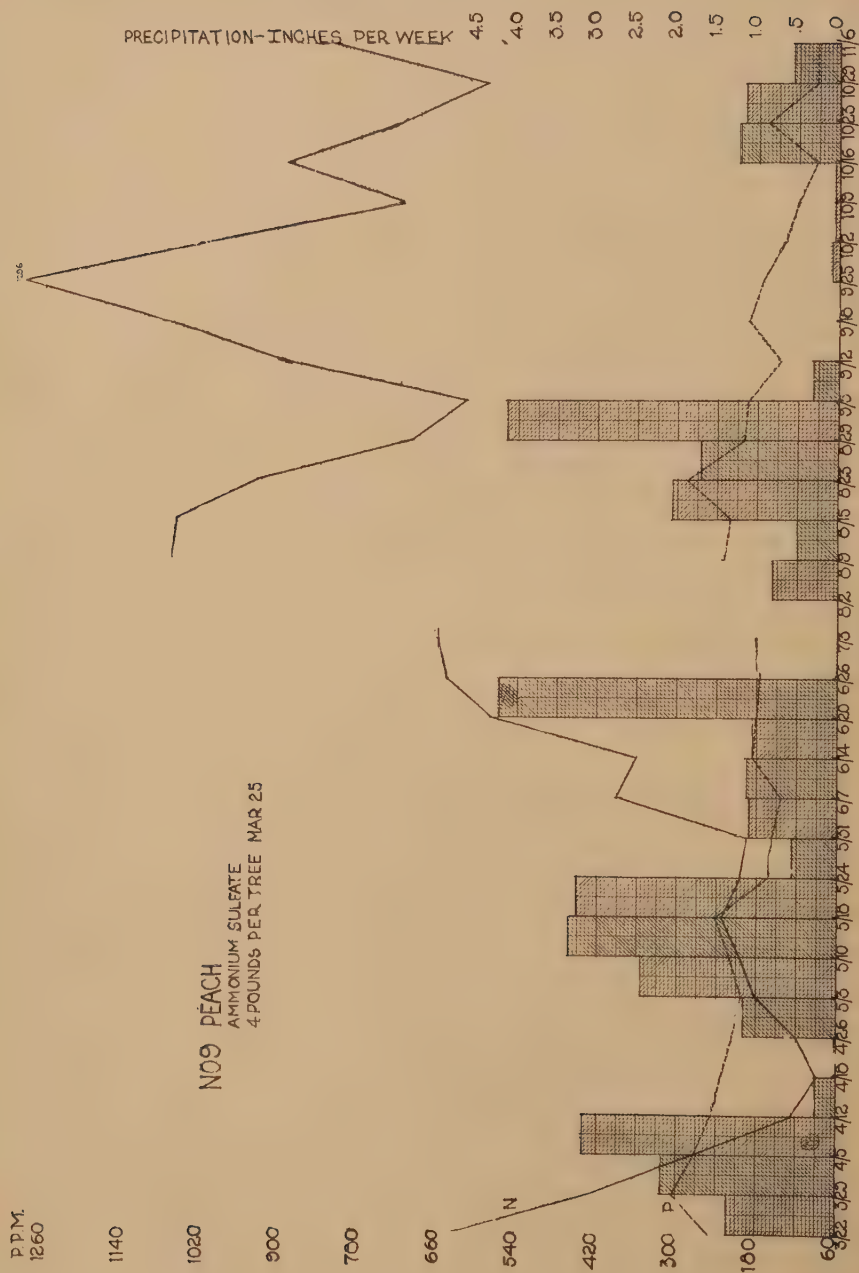
160

80

0

1/1/13 1/1/20 1/1/27 1/2/4 1/2/11 1/2/18 1/2/26 1/2/36 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24 3/31 4/7 4/14 4/21







p.p.m.
1260

1140

1020

900

780

660

N

540

420

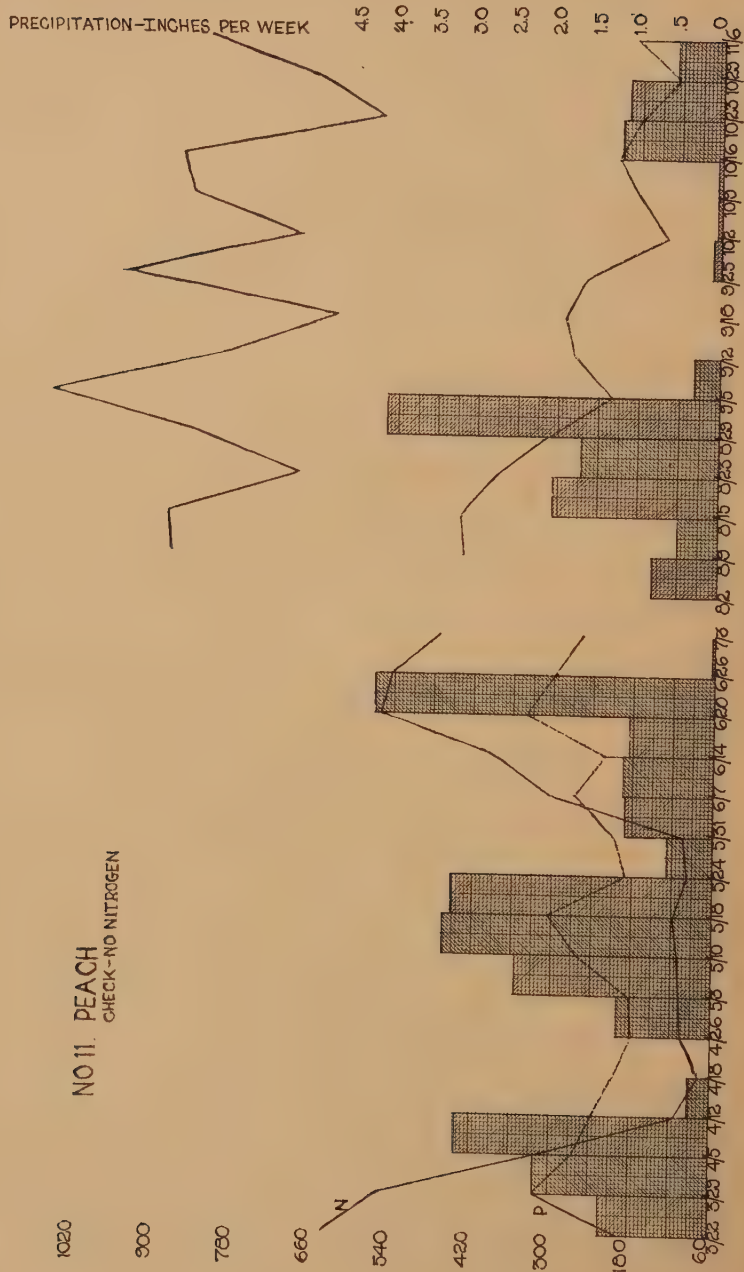
300

180

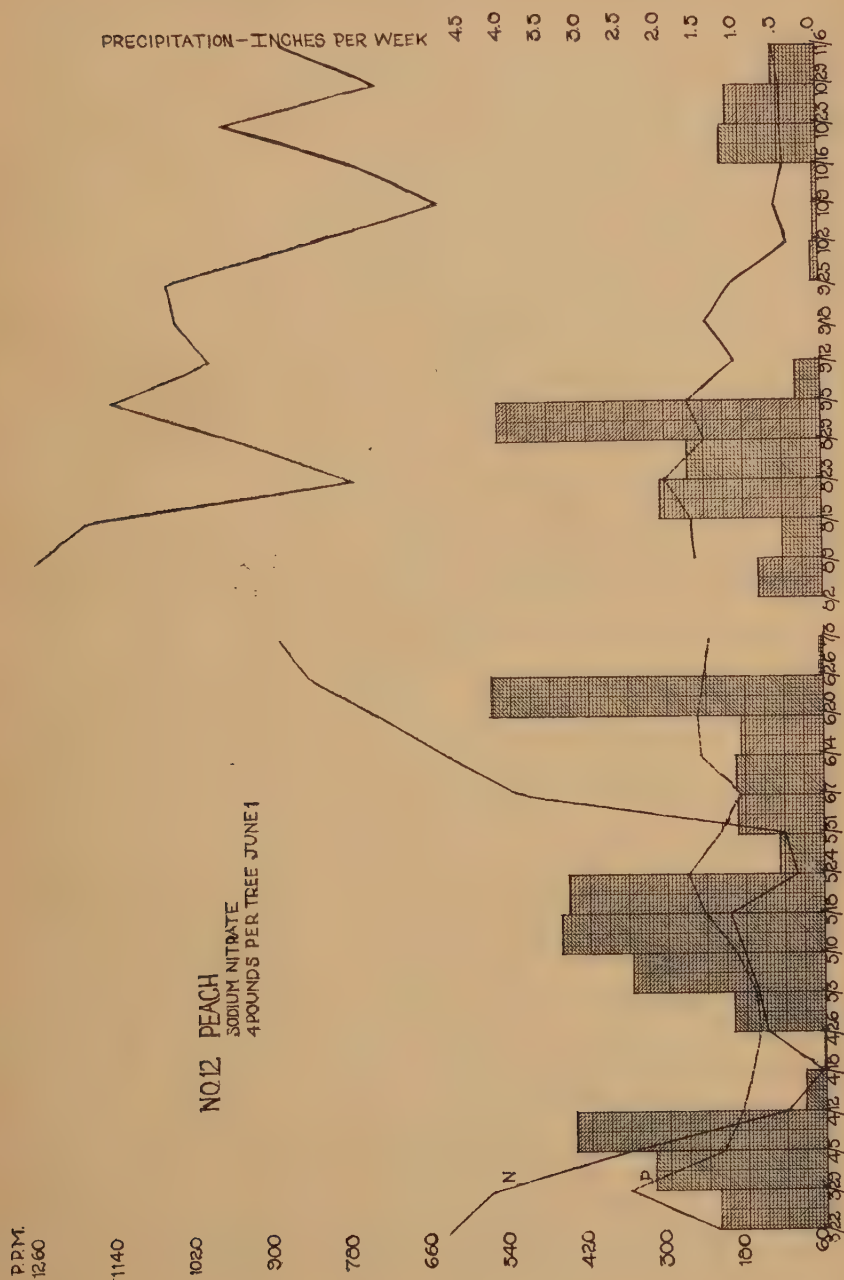
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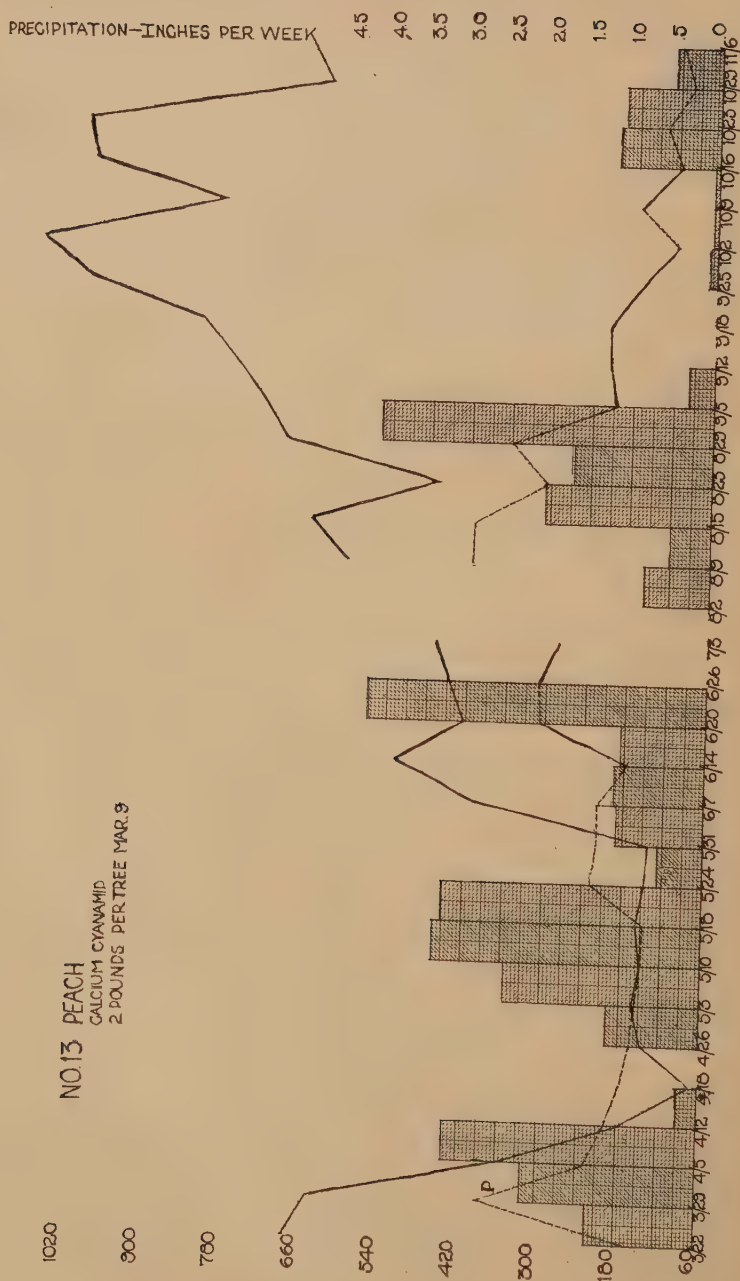
NO 11. PEACH

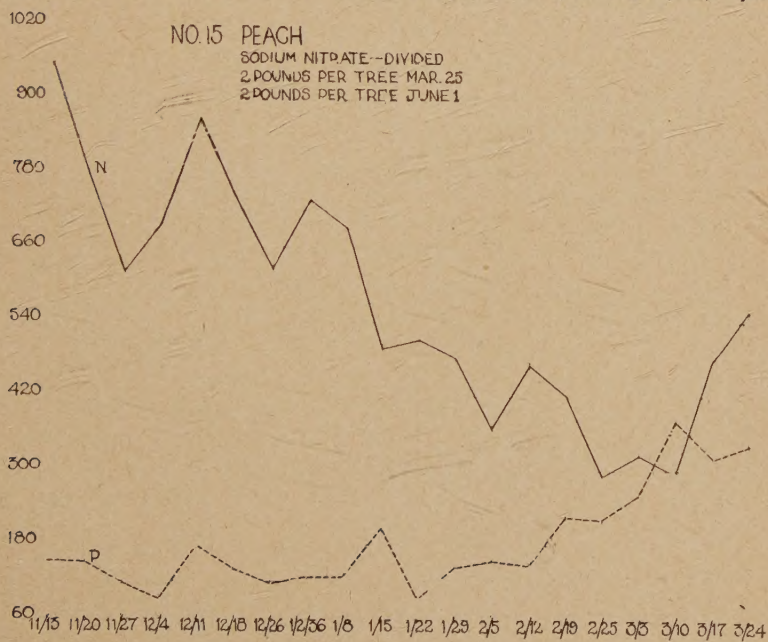
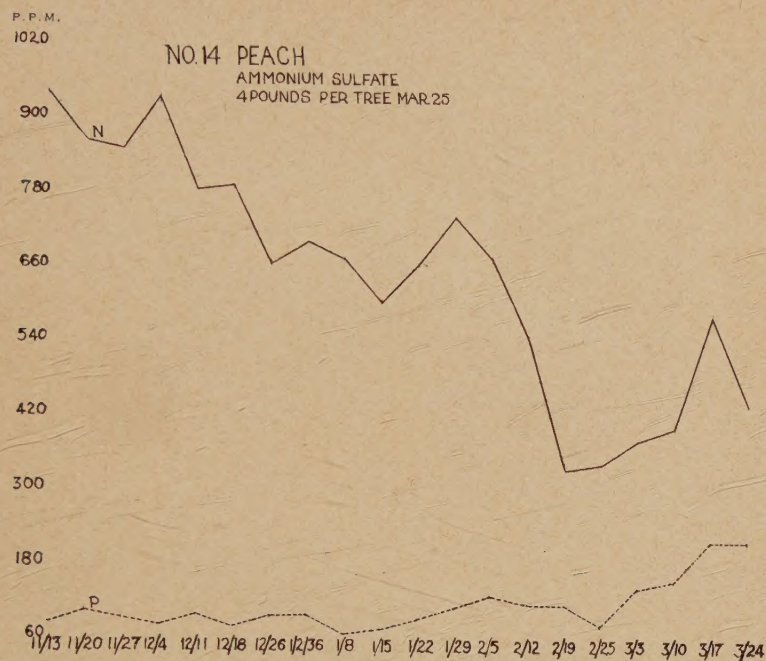
CHECK—NO NITROGEN



Seasonal Course of N and P in Fruit-tree Shoots 187







P. P. M.

1020

NO. 16 PEACH
CHECK—NO NITROGEN

900

780

660

540

420

300

180

60

1140

1020

900

780

660

540

420

300

180

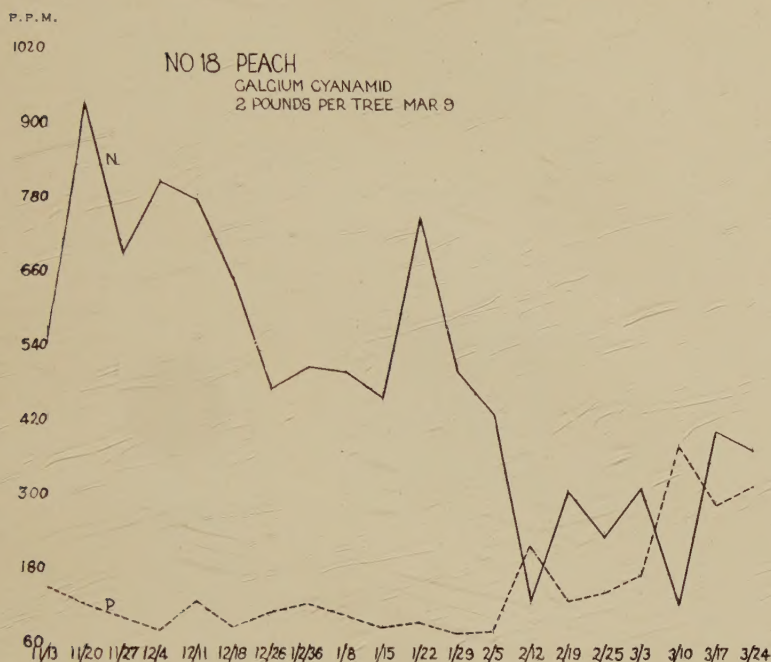
60

1/13 1/20 1/26 12/4 12/11 12/18 12/26 1/2/36 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24

1/13 1/20 1/26 12/4 12/11 12/18 12/26 1/2/36 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24

NO. 17 PEACH
SODIUM NITRATE
4 POUNDS PER TREE JUNE 1

1/13 1/20 1/26 12/4 12/11 12/18 12/26 1/2/36 1/8 1/15 1/22 1/29 2/5 2/12 2/19 2/25 3/3 3/10 3/17 3/24



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